05-R-320, Linac Coherent Light Source, Stanford Linear Accelerator Center, Menlo Park, California

1. Significant Changes

Recent construction bids have been much higher than the baseline estimates, as a result, the conventional facilities scope will not include the planned Central Laboratory Office Complex, but will include renovations to existing buildings. This will address the increased costs while still maintaining the project's full capabilities. A separate project, not associated with the Linac Coherent Light Source project, will renovate space at SLAC for the Photon Ultrafast Laser Science and Engineering (PULSE) Center. Additional details are presented in datasheet 08-SC-11.

2. Design, Construction, and D&D Schedule

(fiscal quarter)

	Preliminary Design Start	Final Design Complete	Physical Construction Start	Physical Construction Complete	D&D Offsetting Facilities Start	D&D Offsetting Facilities Complete
FY 2006	2Q FY 2003	4Q FY 2006	3Q FY 2006	2Q FY 2009	N/A	N/A
FY 2007	2Q FY 2003	4Q FY 2006	3Q FY 2006	2Q FY 2009	N/A	N/A
FY 2008	2Q FY 2003	3Q FY 2008	3Q FY 2006	2Q FY 2009	N/A	N/A

3. Baseline and Validation Status

(dollars in thousands)

	TEC[a]	OPC, Except D&D Costs	Offsetting D&D Costs	Total Project Costs[a]	Validated Performance Baseline	Preliminary Estimate
FY 2006	315,000	64,000	—	379,000	379,000	N/A
FY 2007	315,000	64,000	—	379,000	379,000	N/A
FY 2008	315,000	64,000	—	379,000	379,000	N/A

4. Project Description, Justification, and Scope

The purpose of the Linac Coherent Light Source (LCLS) Project is to provide laser-like radiation in the x-ray region of the spectrum that is 10 billion times greater in peak brightness than any existing coherent x-ray light source. This advance in brightness is similar to that of a synchrotron over a 1960's laboratory x-ray tube. Synchrotrons revolutionized science across disciplines ranging from atomic physics to structural biology. Advances from the LCLS are expected to be equally dramatic. The LCLS Project will provide the first demonstration of an x-ray Free Electron Laser (FEL) in the 1.5–15 Angstrom range and will apply these extraordinary, high-brightness x-rays to an initial set of scientific problems described below. This will be the world's first such facility.

The LCLS is based on the existing SLAC linac. The SLAC linac can accelerate electrons or positrons to 50 GeV for colliding beam experiments and for nuclear and high-energy physics experiments on fixed

[a] The full project TEC and TPC, established at Critical Decision 2b (Approve Performance Baseline), are $315,000,000 and $379,000,000, respectively, and include the costs for PED from project 03-SC-002.

targets. At present, the first two-thirds of the linac is being used to inject electrons and positrons into Positron Electron Project-II (PEP-II), and the entire linac is used for fixed target experiments. When the LCLS is completed, the latter activity will be limited to 25 percent of the available beam time and the last one-third of the linac will be available for the LCLS a minimum of 75 percent of the available beam time. For the LCLS, the linac will produce high-brightness 5–15 GeV electron bunches at a 120 Hertz repetition rate. When traveling through the new 120 meter long LCLS undulator, these electron bunches will amplify the emitted x-ray radiation to produce an intense, coherent x-ray beam for scientific research.

The LCLS makes use of technologies developed for SLAC and the next generation of linear colliders, as well as the progress in the production of intense electron beams with radiofrequency photocathode guns. These advances in the creation, compression, transport, and monitoring of bright electron beams make it possible to base this next generation of x-ray synchrotron radiation sources on linear accelerators rather than on storage rings.

The LCLS will have properties vastly exceeding those of current x-ray sources (both synchrotron radiation light sources and so-called "table-top" x-ray lasers) in three key areas: peak brightness, coherence (i.e., laser-like properties), and ultrashort pulses. The peak brightness of the LCLS is 10 billion times greater than current synchrotrons, providing 10^{11} x-ray photons in a pulse with duration of less than 230 femtoseconds. These characteristics of the LCLS will open new realms of scientific application in the chemical, material, and biological sciences.

The LCLS Project requires a 135 MeV injector to be built at Sector 20 of the 30-sector SLAC linac to create the electron beam required for the x-ray FEL. The last one-third of the linac will be modified by adding two magnetic bunch compressors. Most of the linac and its infrastructure will remain unchanged. The existing components in the Final Focus Test Beam tunnel will be removed and replaced by a new undulator and associated equipment. Two new buildings, the Near Experimental Hall and the Far Experimental Hall, will be constructed and connected by the beam line tunnel. Recent civil construction bids have been much higher than the baseline estimates. As a result, existing buildings at SLAC will be renovated to support LCLS operations. The conventional facilities scope will not include the planned Central Laboratory Office Complex, but will include renovations to existing buildings. There will be no decrease in the project's capabilities and no impact on key technical operating parameters.

The combined characteristics (spectral content, peak power, pulse duration, and coherence) of the LCLS beam are far beyond those of existing light sources. The demands placed on the x-ray instrumentation and optics required for scientific experiments with the LCLS are unprecedented. The LCLS experimental program will commence with: measurements of the x-ray beam characteristics and tests of the capabilities of x-ray optics; instrumentation; and techniques required for full exploitation of the scientific potential of the facility. For this reason, the project scope includes a comprehensive suite of instrumentation for characterization of the x-ray beam and for early experiments in atomic, molecular, and optical physics. The experiments include x-ray multiphoton processes with isolated atoms, simple molecules, and clusters. Also included in the scope of the LCLS Project are the instrumentation and infrastructure necessary to support research at the LCLS, such as experiment hutches and associated interlock systems; computers for data collection and data analysis; devices for attenuation and collimation of the x-ray beam; prototype optics for manipulation of the intense x-ray beam; and synchronized pump lasers.

Beyond the scope of the LCLS construction project, an instrument development program has been implemented in order to qualify and provide instruments for the LCLS. The key element of this program is a Major Item of Equipment—the LCLS Ultrafast Science Instruments (LUSI) project. Instrument

proposals will undergo a scientific peer review process to evaluate technical merit; those concepts that are accepted may then establish interface agreements with the LCLS Project. Expected funding sources include appropriated funds through the Department of Energy and other Federal agencies, private industry, and foreign entities. These instruments will all be delivered after completion of the LCLS line item project. The LCLS Scientific Advisory Committee, working in coordination with the broad scientific community, has already identified a number of high priority initial experiments that are summarized in the document, *LCLS: The First Experiments*. Five specific areas of experimentation are: fundamental studies of the interaction of intense x-ray pulses with simple atomic systems; use of LCLS to create warm dense matter and plasmas; structural studies on single nanoscale particles and biomolecules; ultrafast dynamics in chemistry and solid-state physics; and studies of nanoscale structure and dynamics in condensed matter. The combination of extreme brightness and short pulse length will make it possible to follow dynamical processes in chemistry and condensed matter physics in real time. It may also enable the determination of the structure of single biomolecules or small nanocrystals using only the diffraction pattern from a single moiety. This application has great potential in structural biology, particularly for important systems, such as membrane proteins, which are virtually uncharacterized by x-ray crystallography because they are nearly impossible to crystallize. Instrument teams will form to propose instruments to address these and other scientific areas of inquiry.

Construction funding provided in FY 2006 was for starting physical construction of the LCLS conventional facilities including ground-breaking for the LCLS Near Experimental Hall, Undulator Hall, Beam Transfer Hall, and connecting beam transfer tunnels. In addition, the injector was completed and construction of the downstream linac and electron beam transport to the undulator hall began. Undulator module assembly was started along with construction of x-ray transport/optics/diagnostics systems.

The FY 2007 funding is for continuation of physical construction of the LCLS conventional facilities including the LCLS Near Experimental Hall, Undulator Hall, Beam Transfer Hall, connecting beam transfer tunnels, Far Experimental Hall, and the renovation of existing buildings at SLAC to provide office space requirements to support LCLS operations. In addition, the assembly and delivery of the undulators and undulator infrastructure to SLAC's Magnetic Measurement Facility is planned, as well as the procurements for the x-ray optics, diagnostics, and end stations. Delivery of the undulators in FY 2007 enables achievement of performance goals in FY 2009.

Construction funding requested in FY 2008 is for completion of most of the LCLS conventional facilities and for continued procurement and installation and of the technical hardware.

This project will be conducted in accordance with the project management requirements in DOE Order 413.3A and DOE Manual 413.3–1, Program and Project Management for the Acquisition of Capital Assets.

Compliance with Project Management Order:

- Critical Decision-0: Approve Mission Need—3Q FY 2001
- Critical Decision-1: Approve Alternative Selection and Cost Range—1Q FY 2003
- Critical Decision-2a: Approve Long-Lead Procurement Budget—3Q FY 2003
- Critical Decision-2b: Approve Performance Baseline—3Q FY 2005
- External Independent Review Final Report—3Q FY 2005
- Critical Decision-3a: Approve Start of Long-Lead Procurement—1Q FY 2005

- Critical Decision-3b: Approve Start of Construction—2Q FY 2006
- Critical Decision-4: Approve Start of Operations—2Q FY 2009

5. Financial Schedule

(dollars in thousands)

	Appropriations	Obligations	Costs
Design/Construction by Fiscal Year			
Design			
2003	5,925[a]	5,925[a]	3,644
2004	7,456[a]	7,456[a]	9,713
2005	19,914[a]	19,914[a]	16,805
2006	2,518[a]	2,518[a]	5,066
2007	161[a]	161[a]	746
Total, Design PED (03-SC-002)	35,974	35,974	35,974
Construction			
2005	29,760[bc]	29,760[bc]	7,868
2006	82,170[c]	82,170[c]	61,395
2007	105,740[c]	105,740[c]	141,825
2008	51,356[c]	51,356[c]	53,100
2009	10,000	10,000	14,838
Total, Construction	279,026	279,026	279,026
Total, TEC	315,000	315,000	315,000

[a] PED funding was reduced by $75,000 as a result of the FY 2003 general reduction and rescission, by $44,000 as a result of the FY 2004 rescission, by $161,000 as a result of the FY 2005 rescission, and by $26,000 as a result of the FY 2006 rescission. This total reduction was restored in FY 2005, FY 2006, and FY 2007 to maintain the TEC and project scope.
[b] FY 2005 funding was for long-lead procurements. The scope of work in FY 2005 was expanded to include modification of existing facilities at the Stanford Linear Accelerator Center for testing of the long-lead equipment items.
[c] Construction funding was reduced by $240,000 as a result of the FY 2005 rescission and by $830,000 as a result of the FY 2006 rescission. This total reduction is restored in FY 2007 and FY 2008 to maintain the TEC and project scope.

6. Details of Project Cost Estimate

Total Estimated Costs

(dollars in thousands)

	Current Estimate	Previous Estimate
Preliminary and Final Design (PED 03-SC-002)	35,974	35,974
Construction Phase		
Site Preparation	9,000	9,000
Equipment	110,652	110,652
All other construction	104,974	93,400
Contingency	54,400	65,974
Total, Construction	279,026	279,026
Total, TEC	315,000	315,000

Other Project Costs

(dollars in thousands)

	Current Estimate	Previous Estimate
Conceptual Planning[a]	7,700	7,500
Start-up[b]	50,324	48,383
Contingency for OPC other than D&D	5,976	8,117
Total, OPC	64,000	64,000

7. Schedule of Project Costs

(dollars in thousands)

	Prior Years	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	Outyears	Total
TEC (Design)	35,974	—	—	—	—	—	—	35,974
TEC (Construction)	211,088	53,100	14,838	—	—	—	—	279,026
OPC Other than D&D	25,208	16,242	22,550	—	—	—	—	64,000
Total, Project Costs	272,270	69,342	37,388	—	—	—	—	379,000

8. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy (fiscal year)	3Q FY 2009
Expected Useful Life (number of years)	30
Expected Future start of D&D for new construction (fiscal year)	N/A

[a] Costs in this category include NEPA, conceptual design, and R&D.
[b] Costs in this category include start-up (pre-operations) and spares.

(Related Funding Requirements)

(dollars in thousands)

	Annual Costs		Life cycle costs	
	Current Estimate[a]	Prior Estimate	Current Estimate[b]	Prior Estimate
Operations	25,000	25,000	N/A	N/A
Maintenance	25,000	25,000	N/A	N/A
Total Related Funding	50,000	50,000	1,909,000	1,909,000

FY 2010 is expected to be the first full year of LCLS facility operations. The current estimate is preliminary and based on historical experience with operating similar types and sizes of facilities. This estimate will be refined as the LCLS Project matures.

The estimate includes LCLS facility operations only. It does not include operation of the SLAC linac which is funded by HEP in FY 2005 and prior years, but begins a 2 to 3 year transition to BES funding beginning in FY 2006. Operation of the SLAC Linac is essential to the operation of the LCLS.

9. Required D&D Information

Not applicable.

10. Acquisition Approach

A Conceptual Design Report (CDR) for the project was completed and reviewed. Key design activities were specified in the areas of the injector, undulator, x-ray optics and experimental halls to reduce schedule risk to the project and expedite the startup. Also, the LCLS management systems were put in place and tested during the Project Engineering and Design (PED) phase. These activities are managed by the LCLS Project Office at SLAC, with additional portions of the project being executed by staff at Argonne National Laboratory (ANL) and Lawrence Livermore National Laboratory (LLNL).

The design of technical systems is being accomplished by the three collaborating laboratories. The conventional construction design aspect was contracted to an experienced Architect/Engineering (A/E) firm to perform Title I and II design. Title I design was completed in FY 2004. Title II design began in FY 2005 and was completed in FY 2006. An experienced construction Manager/General Contractor is under contract to carry out conventional facilities construction.

[a] LCLS is currently under construction and normal operations are expected to begin in the 3Q FY 2009. The Annual Cost estimate shown in the table above is for a full year of operation.
[b] Assumptions: $379,000,000 TPC; $50,000,000 annual costs for 30 years; $30,000,000 de-commissioning.